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The control and monitor system for the BESIII ETOF/MRPC beam test*

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A test system is developed for the BESIII ETOF/MRPC beam tests of data acquisition, environment monitoring and automatic control. The software framework is based on the CAMAC bus, VME bus and Serial Port, which are responsible for communications with the detectors. The monitor system works well in the beam test.

Keywords: Beam test, Data acquisition system, Monitor and control system

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I. INTRODUCTION

For the advanced physics goal, the endcap time of flight counter (ETOF) in Beijing Spectroscopy III (BESIII) [1] is planned to upgrade by using multi-gap resistive plate chamber (MRPC) detector to replace plastic scintillators coupling with Photomultipliers (PMTs) [2]. To improve the total timing resolution of updated ETOF from 110 ps to 80 ps for μ, the intrinsic timing resolution of MRPC detector should be less than 50 ps.

During the BESIII TOF R&D process, the parameters such as the operation voltage of PMT, and the shape of scintillator were carefully studied in the beam test for the original TOF prototype to achieve designed timing resolution [3, 4]. It is necessary to study the characteristics of MRPC by using cosmic-rays or accelerator particle beams (electrons or hadrons). According to the plan, a beam test will be done in the E3 line of the IHEP (Institute of High Energy Physics) beam factory for studying performance of the MRPC module carefully. To get an efficient data acquisition system, a control and monitor system is necessary for the MRPC prototype module beam test.

Silica aerogel is a unique material with a refractive index between those of condensed phases and gases. It has thus been used as Cherenkov radiator in a verity of applications. An aerogel threshold Cherenkov counter was developed for the upgraded BEPC (Beijing Electron Positron Collider) E3 beam line [5] at IHEP to discriminate electrons from pions. The E3 line is a mixed beam bunch of electrons and hadrons (pions and protons). TOF detector is always used to distinguish pions from protons by the flying time, and Cherenkov counter can select electrons from the mixed particle bunch. There is already a gaseous Cherenkov counter with a length of 1.2 m using CO_2 as radiator, but its volume is large and its detection efficiency fluctuates with temperature, hence the need of a new detector.

Because momenta of the electrons and pions in the E3 line are in the range of 100–1100 MeV/c and 400–900 MeV/c, respectively, a threshold Cherenkov counter with low refractive index radiator is the best candidate for this purpose. Using silica aerogel with an index of refraction $n = 1.01$ only electrons emit Cherenkov light, whereas the velocities of pions are below the threshold velocity.

II. EXPERIMENTAL

The E3 line is a mixed beam bunch of electrons, pions and protons, in momenta of 0.3–1.2 GeV/c. There are several detectors with different functions for the beam test located in the E3 line, and the relative position is shown in Fig. 1.

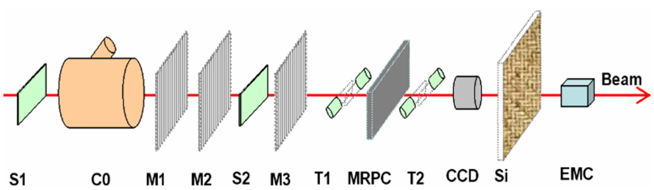

Fig. 1. (Color online) Layout of detectors in the E3 beam line, referring the text for explanations of the acronyms.

The Cherenkov counter (C0) selects electrons from the mixed particle bunch. The scintillator counters (S1, S2) distinguish pions from protons by flying time. Particle track can

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be reconstructed by the three parallel Multiwire proportional chambers detectors (MWPC, M1, M2 and M3), the silicon micro strip (Si) and the intensified camera detector (CCD) at the back of MWPC. At the end of beam, electromagnetic calorimeter (EMC) is used to identify particles by the energy deposition of particles.

A toughly strict timing start/stop is offered by the T0 detector. This kind of T0 consists of four counters, each couples in one edge with a plastic scintillator (BC420) plus a PMT (Hamamastu H6533 with a 700 ps rise time and 160 ps ps transit time spread), and with an aluminum film in the other edge. The MRPC detector is put on the flat roof, which can be controlled remotely. The four counters are fixed at the side of flat roof symmetrically to eliminate time error caused by the beam position uncertainty.

A. Electronics for the beam test

The detectors in the E3 beam line have different data acquisition systems (DAQs), as shown in Fig. 2(a). The detectors work respectively, but there must be a one-to-one correspondence between data flows from different detectors. So a common trigger signal must be provided for starting the data acquisition. It can be produced after the C0 veto signal is coincided with S1, S2 and four T0 counters signals. Detailed electronics trigger logic is shown in Fig. 2(b). In order to improve the precision of time measurement, leading edge discriminators (LED_Dis) are used instead of constant fraction discriminators, and the effect of timing measurement caused by different signal amplitude (time walk effect) can be eliminated by time-amplitude corrections.

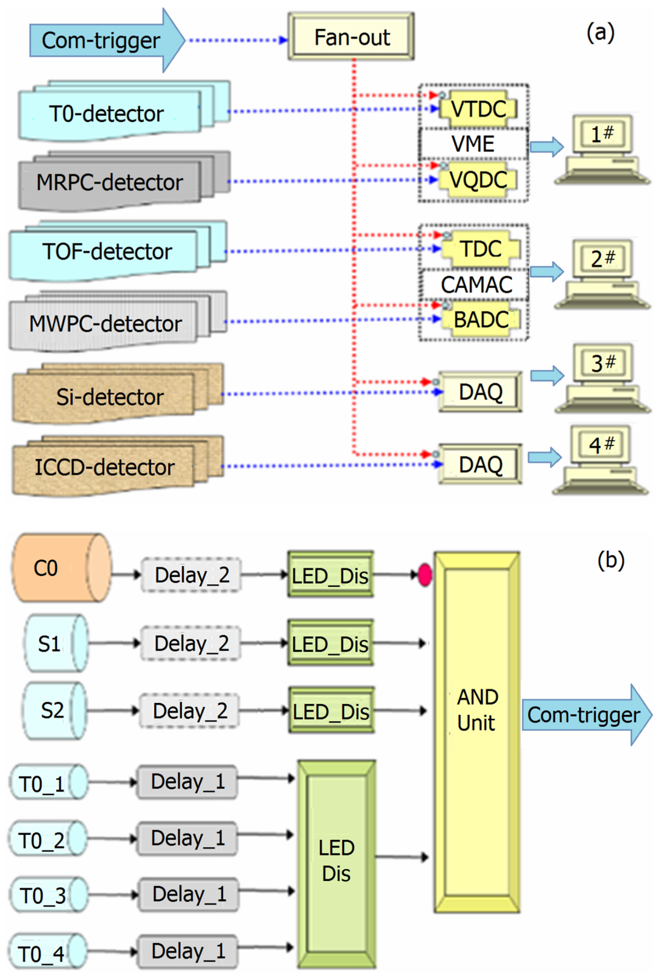

Fig. 2. (Color online) Data acquisition systems (a) and electronics trigger logic (b) in the beam test.

III. SUB-DAQ BASED ON CAMAC SYSTEM

There are 32 channels of cathode signal (16 cathode wires on each X and Y cathode plane, respectively) and 1 channel anode signal from each wire chamber. Hundreds of signals are sent from the three MWPC detectors. On basis of the cost and efficiency, analog-to-digital conversion is completed by Brilliant ADC (Analog-to-Digital Converter) (BADC), a brilliant CAMAC (Computer Automated Measurement And Control) module. One BADC complete A/D conversion, pedestal removing, gain transform, nonlinear correction, and temporary data store of up to 200 channels by time-share gating of the front end circuit under the control of a high speed programmable CPU (Central Processing Unit). Flexibility of the CAMAC is enhanced by various configurations of BADC [6]. CAMAC TDC (Time to Digital Converter) module is used to acquire the flying time of S1 and S2 to distinguish mixed particles. The particle energy deposition in EMC is measured by another ADC module of CAMAC type.

IV. SUB-DAQ BASED ON VME SYSTEM

The CAMAC system in precisions of 250 fC/LSB QDC (Charge to Digital Converter) and 250 ps/LSB TDC is good enough for most industrial measurements. For the T0 and MRPC signal measurement, the VME (Versa Module Eurocard) system of higher precision is used to get the better result. Intrinsic timing resolution of the T0 detectors, as tested with cosmic rays, is about 41.58 ps (= sigma×LSB = 1.663×25 ps) [7] (Fig. 3(a)).This can be achieved only by the VME system in precisions of 25 fC/LSB QDC and 25 ps/LSB TDC. In the same way, as shown in Fig. 3(b), the intrinsic timing resolution of T0 is 65.5 ps (= sigma×LSB = 0.262×250 ps) after transforming VME data (25 ps/LSB) to general CAMAC data (250 ps/LSB). So in the same condition, the precision of testing data will be improved if the high precision DAQ system is used.

According to the single photoelectron spectra (SPE), behaviors of the PMT under different operation voltages, including energy resolution of the SPE, peak-vale value etc, can be carefully studied to search suitable operation status,

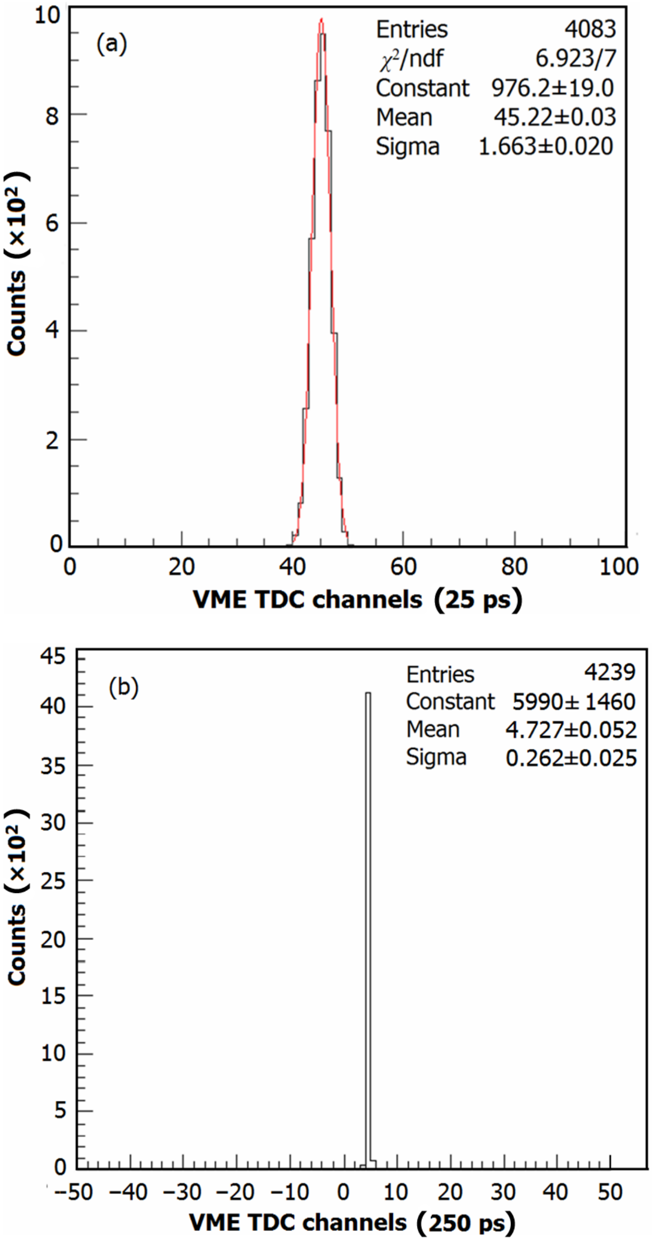

Fig. 3. (Color online) Results of T0 using cosmic rays under DAQ systems of different precisions.

thus the T0 detector can achieve better timing resolution [8]. In this beam test, the V965 module with 25 fC/LSB acquires 4 channels of charge from T0 detector, and the V792N module of 100 fC/LSB precision acquires 12 channels of charge from MRPC. The timing data including the 4 channels of T0 detector, 12 channels of MRPC detector are acquired by the V1290N module with 25 ps/LSB.

It is hard to eliminate noise in the data processing and to do the right T-A corrections by acquiring charge or timing of MRPC and PMT separately. So it is necessary to measure the charge and timing from MRPC and PMT synchronously, and good events can be selected according to match of charge and timing. The trigger signal is divided into several channels and sent into the QDC and TDC modules, which are connected in daisy chain way. The read out mode of the VME boards is Chain Block Transfer (CBLT), with which the data from QDC can correspond to the data from TDC, so it can reduce system evidently and realize the match of timing and charge even if in the high counting rate situation.

V. MONITORS TO THE BEAM TEST SYSTEM

MRPC, a gaseous detector, is affected by the gas ratio, flux, atmospheric pressure, temperature and humidity [9]. So the temperature, humidity and the atmospheric pressure must be monitored.

A. HV monitoring and control

The operation voltage of T0 detectors is different from MRPC, and two HV systems, SY127 HV crate and NIM HV module N470 (in the variance of ±1 V), are used in the MRPC beam test. The HV module supplying operation voltage for the T0 detectors is of ±4000 V, while the N470 module for MRPC is of ±7000 V. The SY127 carte can be controlled by RS232, the CAMAC module C139, or the VME module V200 [10], but the C139 and V200 are no longer in production, hence the only choice of RS232. According to operational principle of serial port, a software framework based on RS232 is developed for reading and writing serial port to control the SY127 crate. Also, SY127 can be replaced by SY1527, a new HV system with lower variance and a better communication interface.

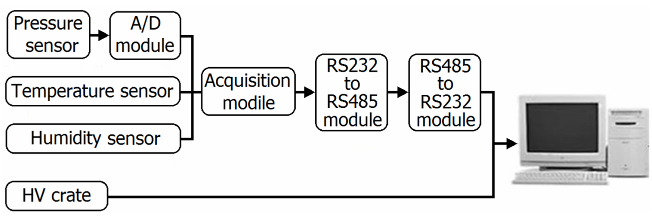

Fig. 4. Sketch of environment monitoring system.

B. Environment monitoring system

The temperature, humidity and atmospheric pressure in the working environment should be recorded to correct the experiment results. The location of the acquisition modules in the experiment environment is far from the control room. To avoid signal attenuation caused by long-distance data transmission, the output from acquisition modules is transmitted adopting the RS485, and the converter modules convert signal between the RS485 and the RS232. The hardware includes also temperature and humidity modules (LTM8901E), A/D converter modules (LTM8903), RS485/RS232 converter

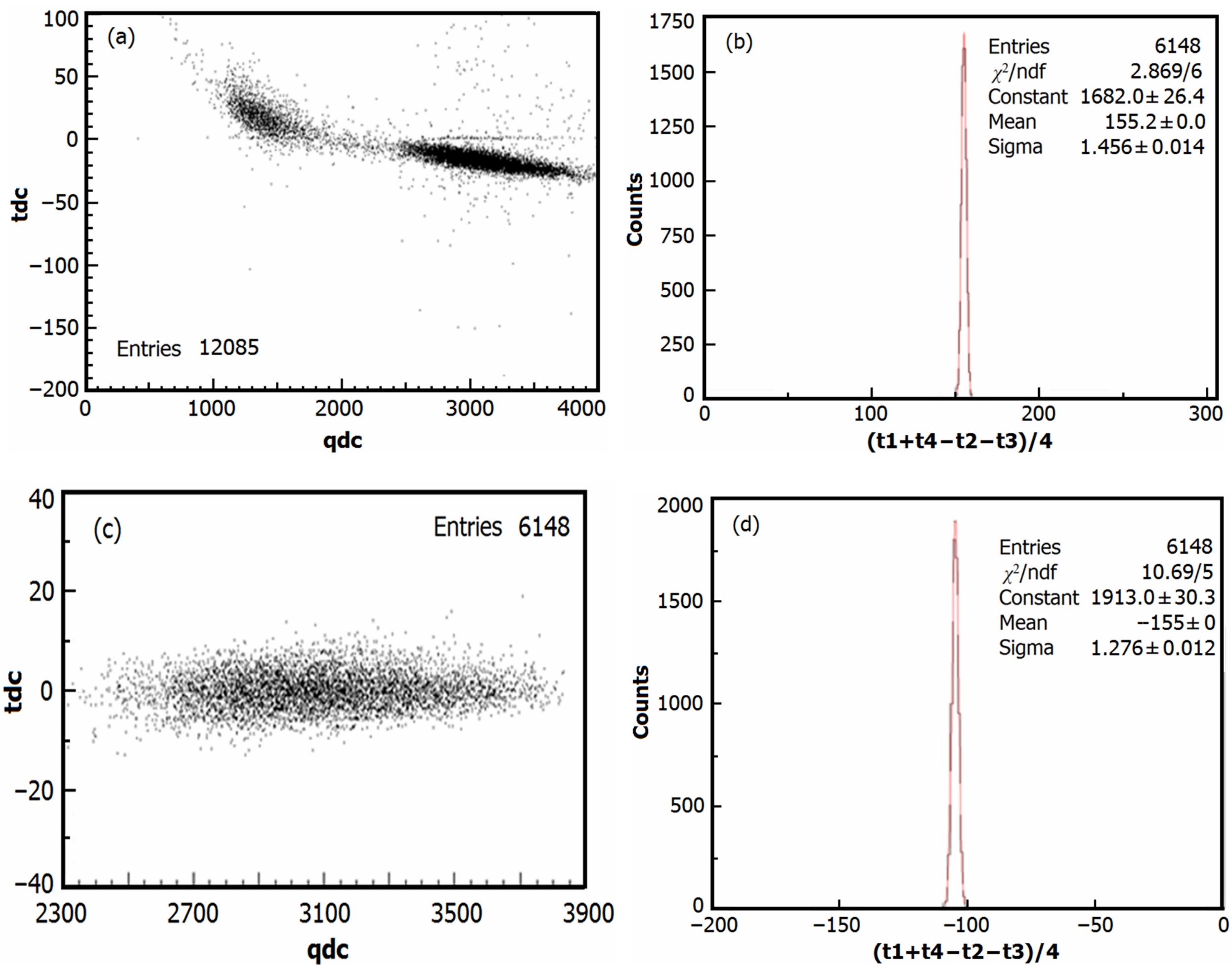

Fig. 5. (Color online) Primary results of timing resolution of the T0 detector.

modules (LTM8920), acquisition modules (LTM8662), and pressure sensors (PMP1400).

Figure 4 shows schematically the environment monitoring system. The pressure sensor sends analog signal of 0–5 V, so an A/D converter module is needed; while the temperature and humidity modules include A/D converter, so the signals can be connected to the acquisition module directly. The hexadecimal data from all the channels can be acquired by using the VISA Read function of LabVIEW, and the results are written into the MySQL data base.

C. Data quality monitoring system

Efficiency should be increased as high as possible, and experimental data should be of good statistics, which means longer cycle of data acquisition is required. So data processing and statistical analysis are needed to know the status of detectors in time. The detectors' status should be displayed online to shifters for dealing with abnormal situation. To achieve these goals, Data Quality Monitoring Software (DQM) cooperating with DAQ is developed to monitor the data quality. C++ code based on ROOT encapsulated into Dynamic Link Library is used to analyze spectrum data by the calling in LabVIEW [11].

VI. RESULTS AND DISCUSSION

The scheduled plan was fulfilled successfully and experiment data were acquired through this beam test system. Fig. 5 shows a primary result about timing resolution of T0 detector in the beam test. Without any correction, Fig. 5(a) is a timing-amplitude discrete figure, in which X axis is timing and Y axis is amplitude. Fig. 5(b) is a timing histogram, and the fitting result shows the timing resolution is 36.4 ps (=$\sigma\times$LSB = 1.456×25 ps). After the time-amplitude correction for the proton data were selected from the raw data, as shown in Fig. 5(c), the timing resolution of T0 detector could achieve 31.9 ps (Fig. 5(d)). The analysis of MRPC data can be seen in detail in Ref. [2].

VII. SUMMARY

A test system has been developed for the BESIII ETOF/MRPC beam test. It converts the data from T0 system consisting of PMTs and MRPC detector from analog to digital, and ensures data taking with the same triggers, so as to realize a one-to-one correspondence between data flows from different detectors. So an electronics trigger logic in the hardware is realized by adjusting different detector signal delay, and a CBLT method is used in the software for multi electronics modules. Also, QDCs and TDCs of high accuracies are used for measuring charge and time precisely. And a monitor system for high voltage and environment is developed. The timing resolution of T0 detector could achieve 31.9 ps by offline data analysis. It proves that the test system realizes the goal of development.

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